U.S. Patent Application S.N. 09/525,247

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: URIU, et al.

Serial No.: 09/525,247

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For: INDUCTOR AND METHOD FOR PRODUCING THE SAME

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DECLARATION UNDER 37 CFR §1.132

Date: March 7, 2002
Assistant Commissioner for Patents
Washington, DC 20231

Dear Sir:

1. I, Eiichi URIU, have the following postal address: 2-17-5, Higashikori, Hirakata-shi, Osaka, Japan

2. I graduated from Osaka University, Japan, in 1984 with a Bachelors degree in Engineering.

3. I have been employed by Matsushita Electric Industrial Co., Ltd. since 1984. I have been engaged in the research of lamination ceramic chip inductors, which is the subject matter of the above-identified application, since 1994. I am one of the inventors of the invention of the above-identified application, and I am fully familiar with the subject matter thereof.

4. Based on my experience with the subject matter of the above-identified application, I conducted the following experiments to observe the effects of producing conductive patterns by electroforming, such conductive

patterns used in lamination ceramic chip inductors as recited in the claims of the subject application.

I also conducted experiments to observe the effects of producing conductive patterns by printing methods, such as those disclosed in United States Patent No. 5,515,022 to Tashiro et al. (hereinafter, Tashiro), and Japanese Laid-Open Publication No. 6-112047 to Hirohashi (hereinafter, Hirohashi) instead of electroforming.

Experiments

1. Experiment details

In the following experiments, laminated ceramic chip inductors were made by each of the two methods, first, according to the subject application, and second, according to Tashiro and Hirohashi. The respective experiments differed only in the method of forming the conductive pattern, in order to make a direct comparison of the characteristics of the resultant samples produced by the two methods. Otherwise, the respective experiments used the same conditions, for example, the use of green sheets, conditions for forming the laminated layers, sintering temperature, and the like. The following is a description of the processes used to produce the samples according to the subject application and Tashiro (and Hirohashi).

1.1. A slurry was manufactured by mixing a Ni∘Zn∘Cu ferrite powder (having an average particle diameter of 0.8 μm), a binder resin of butyral(polyvinylbutyral), a solvent of butyl acetate, and a plasticizer of dibutylphthalate, and then, a green sheet having a thickness of 200 μm was made from the slurry using a doctor blade (in accordance with the description at page 23, lines 11-30 of the specification of the subject application; col. 8, lines 8-13 and 48-64 and col. 9,

lines 44-53 of Tashiro; and col. 3, lines 35-37 of Hirohashi).

1.2. Then, a conductive pattern was formed on the green sheet as follows in accordance with the printing method of Tashiro and Hirohashi (hereinafter, printing method) and the electroforming method of the subject application (hereinafter, electroforming method).

In the printing method, the conductive pattern was formed in a particular pattern on the green sheet so as to have a thickness of 12 μm, after drying, and a width of 50 μm, by performing a printing process of a conductive paste including conductive particles, having a main component of silver, the binder resin and the solvent by using a 360 mesh screen (in accordance with the description at col. 6, lines 16-23 and col. 7, lines 1-4 of Tashiro; and col. 3, lines 38-40 of Hirohashi).

In the printing method, the width of 50 μm is a boundary condition for providing thin conductive lines and a thickness of the conductive lines cannot be made more than 12 μm after drying. If it is attempted to make the width less then 50 μm or the thickness greater than 12 μm, an irregular and blurred conductive pattern results. This is explained as follows.

In the printing method a mesh and emulsion arrangement is used where the conductive paste is pressed through the mesh in the pattern of the emulsion, which is the inverse to the conductive pattern to be formed, so that the conductive pattern is formed on the greensheet. In relation to mass-production, the practical limit of the pitch of the emulsion (i.e., width of the conductive pattern) has been found by myself and my co-inventors of the subject application to be 80 μm, so as to enable the formation of a fine conductive pattern without disconnection or blurring.

Blurring is the condition where the edge of the conductive pattern is spread. That is, the edge of the patterned line is not sharp due to the build-up of conductive paste on the edges of the emulsion after many production runs using the same mesh and emulsion.

However, for producing samples in a single run (i.e., non mass-production of conductive patterns) a limit of 50 μm is possible as explained below.

Forming the conductive pattern by printing through an emulsion with a pitch less than 50 μm has the effect of producing a disconnected pattern, with the printing of the conductive paste onto the greensheet being in correspondence with the mesh holes. In order to form a fully connected pattern, increased pressure can be used to force the paste through the mesh, however this results in the edge of the pattern not being straight (i.e., zigzagged). Therefore, the printing of a fine, fully connected pattern is not possible for pattern widths of less than 50 μm.

Moreover, the thickness of the emulsion pattern governs the thickness of the printed conductive pattern. If the thickness of the emulsion is too large then printing of all of the conductive paste onto the greensheet as the conductive pattern is not practically possible, since some of the paste adheres to the emulsion. This results in a conductive pattern which is not uniform, and which has irregular and blurred edges. Therefore, the formation of a conductive pattern with a thickness greater than 12 μm by printing does not result in a fine pattern in practice.

In the electroforming method, the conductive pattern was formed in a particular pattern on the green sheet so as to have a width of 40 μm and a thickness of 20 μm by

silver plating the conductive pattern onto a conductive base plate using an electroforming process and then transferring the conductive pattern onto the green sheet (in accordance with the description at page 16, line 1-page 23, line 9 of the specification of the subject application).

1.3. The respective green sheets having the conductive patterns formed thereon by the printing method and the electroforming method were subsequently laminated by placing the respective green sheets between two green sheets not having conductive patterns thereon by pressing the sheets together at a temperature of 90°C and a pressure of 70 Kg/cm^2 for 2 seconds to produce a lamination body (in accordance with the description at page 24, line 28-page 25, line 4 of the specification of the subject application).

The lamination was then completed by pressing the lamination body at a pressure of 500 Kg/cm^2 for 20 seconds so as to form an integral body. After the integral body was formed, the resultant green sheet was then cut to form a plurality of integral bodies, and the integral bodies were sintered at a temperature of 900°C for 2 hours (in accordance with the description at page 25, lines 12-20 of the specification of the subject application; col. 7, lines 14-22 and col. 9, lines 5-17 of Tashiro; and col. 4, line 4 of Hirohashi).

The respective sintered integral bodies were then shaped by barrel polishing, and an outer electrode was formed thereon so as to contact an external terminal of the respective conductive patterns disposed within the sintered integral bodies. Finally, the resultant integral bodies were sintered again at a temperature of 700°C to form the respective lamination ceramic chip inductors (in accordance with the description at page 25, lines 22-28 of the specification of the subject

application; col. 9, lines 29-36 and 61-64 of Tashiro; and col. 4, lines 4-9 of Hirohashi).

1.4. The resultant respective lamination ceramic chip inductors were cut in cross-section and polished along the cut, in order to observe the interior of the resultant inductors and thereby inspect the differences between the respective inductors having conductive patterns formed by the printing method and the electroforming method. The results of such inspection and comparison are detailed below.

2. Results of experiments

The above-described experiments obtained the following results with respect to the conductive pattern formed using the printing method and the conductive pattern formed using the electroforming method.

2.1. Results of printing method

Below Figure A shows an image of an experimental laminated ceramic chip inductor sample 1 including a conductive pattern formed between a pair of insulation layers (green sheets) using the printing method as described above.

As can be clearly seen from Figure A, in this printed conductive pattern a specific gap is formed. Specifically, the conductive pattern formed by the printing method first has a thickness of about 12 μm, however after sintering the thickness is reduced by about 40% to about 7 μm due to shrinkage. Thus, as can be clearly seen from Figure A, a specific gap of about 2-5 μm is formed between the conductive pattern and each of the insulation layers.

The shrinkage of the integral body having the conductive pattern itself is about 13%, such that it is assumed that the difference in the shrinkage of the conductive pattern

and the shrinkage of the integral body results in the formation of the specific gap. The shrinkage of the conductive pattern in the printing method is caused by the evaporation of the binder resin and the solvent in the conductive paste making up the conductive pattern as a result of the sintering.

Such a specific gap renders the printed conductive pattern susceptible to contaminants, such as water or plating solvent, which may become present in this gap. Such contaminants can change the characteristics, such as the resistance or impedance, of the printed conductive pattern, therefore changing the characteristics of the inductor formed using this printed conductive pattern.

Thus, the formation of such a specific gap, as in the above-described printing method of Tashiro and Hirohashi, is clearly undesirable since the desired properties of the inductor can not be obtained.

2.2. Results of electroforming method

Below Figure B shows an image of an experimental laminated ceramic chip inductor sample 2 including a conductive pattern formed between a pair of insulation layers (green sheets) using the electroforming method as described above.

As can be clearly seen from Figure B, in this electroformed conductive pattern no specific gap is formed. This is because the conductive pattern formed by the electroforming method is formed by metal plating, without the use of any constituent materials which evaporate as a result of the sintering performed, such that no shrinkage occurs (as reported in the description at page 26, lines 7-14 of the specification of the subject application).

I further declare that all statements made herein of my own knowledge are true and all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Executed on March 7, 2002

Eiichi Uriu
(Eiichi URIU)